University of Saskatch
Department of Electrical E

EE372 Electronic Materials and Devices
Midterm Examination
Professor Robert E. Johanson

PART A
(closed book)

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Welcome to the EE372 Midterm. The examination has two parts. Part A consists of questions that test knowledge of basic concepts, and part B requires more involved calculations. Part A is closed book and closed notes. When you finish part A, hand it in (raise your hand) and then proceed to part B. Part B is open book; you may refer to your textbook (Kasap, any edition) but not to any other material such as notes or other books. You may also use a calculator for both parts. The examination lasts **2** hours.

Each problem is weighted equally. Show your work if the question involves more than a simple answer; credit will be given only if the steps leading to the answer are **clearly** shown. Partial credit will be given for partially correct answers but only if correct intermediate steps are shown. Write your answers on these pages.

For part A, answer 4 of the 5 questions. Do not answer more than 4 questions.

1. 10
2. 10
3. –
4. 9
5. 8

total 37/40

1. Photoelectric Effect

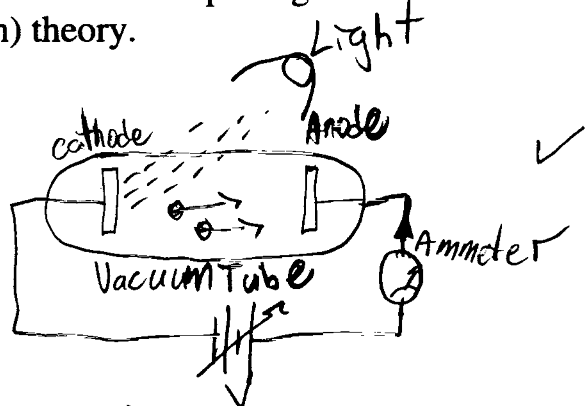
a) Circle any of the following that can be determined directly by data from a photoelectric experiment.

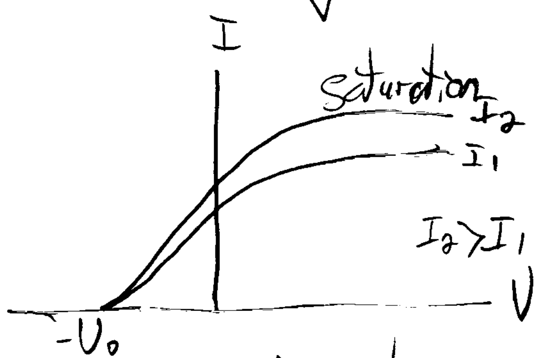
- The ratio of charge to mass for the electron
- The metal's work function
- The uncertainty in the position of the electron
- The photon's energy
- The value of Planck's constant
- The electron's DeBroglie wavelength

b) Sketch the apparatus and draw typical I-V curves for two different wavelengths of light and two different intensities. Indicate which is the longer wavelength and which is the greater intensity.

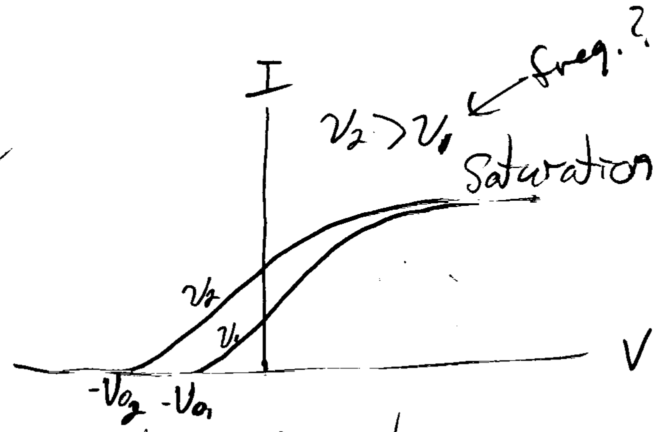
c) Explain what is surprising about the I-V curves from the viewpoint of classical (pre-quantum) theory.

b)





Two different I's



two different ν's

c) Classically we would think increasing I to ↑ Energy ~~of photons~~ of wave as $\underbrace{I = \frac{1}{2}\varepsilon_0 E^2}_{\text{classical}}$ but we find that ↑ intensity only increases the # of photons and that to increase E of photons we must ↑ ν since $E = \underset{\text{constant}}{h}\nu$ $\therefore E \propto \nu$.

X. Semiconductor Band Structure

Draw a qualitative density-of-states diagram for *p*-type silicon. Label all relevant energy levels with appropriate symbols, and name the various regions of the density-of-states. Indicate the approximate position of the Fermi energy.

Silicon

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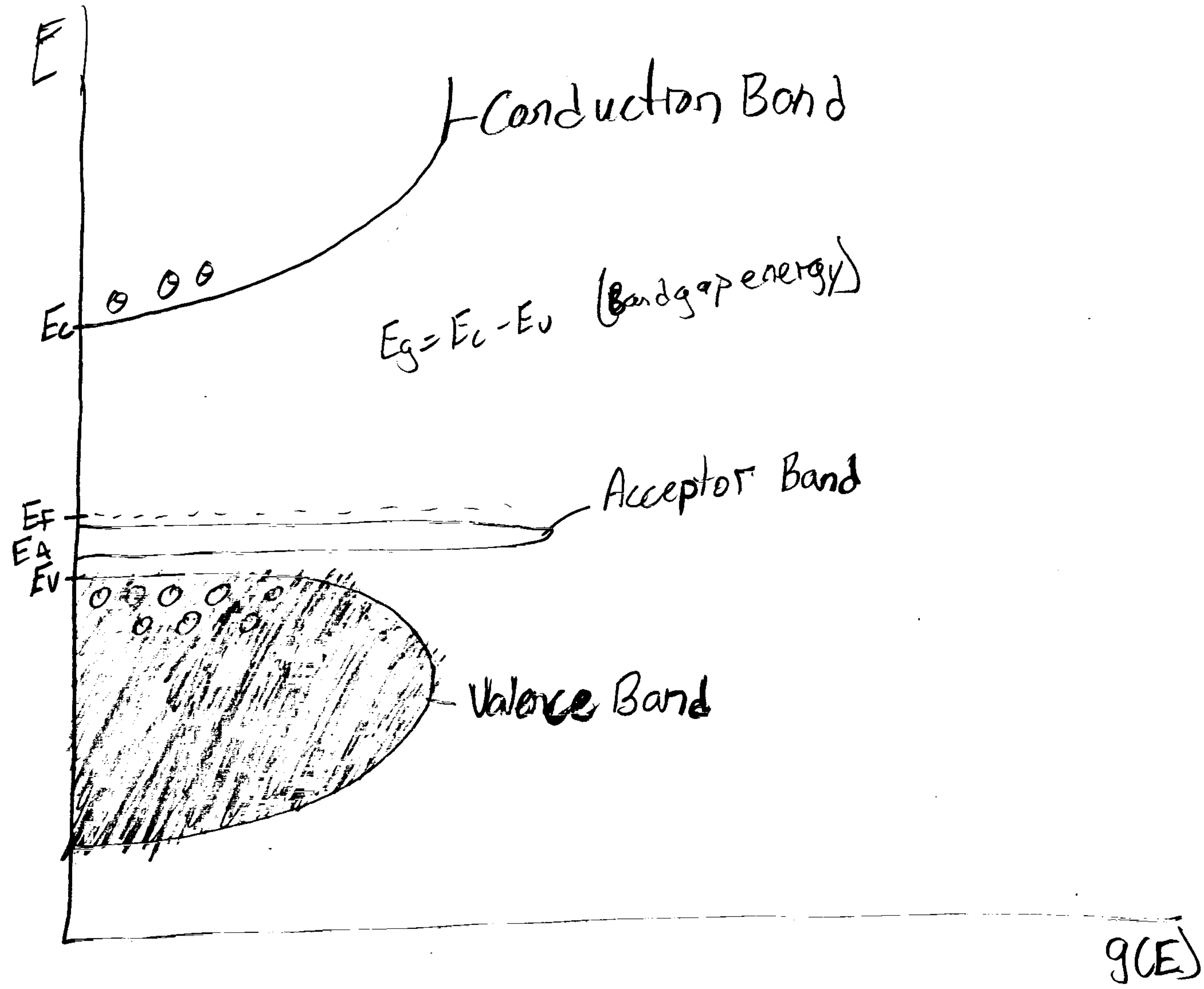

Few e⁻'s in CB from Thermal Energy.

Lots of holes in VB B/c Acceptors take e⁻s from VB.

3. Conduction in Semiconductors

a) Explain qualitatively the processes that limit the drift velocity of an electron traveling through a semiconductor.

b) Draw a qualitative graph of the density of electrons in the conduction band vs. temperature for n-type silicon. Provide an explanation why each region of the curve looks the way it does. The graph should be $\ln n$ vs. $1/T$.

c) Explain why a completely full band does not conduct electricity.

d) Under what circumstances will there be a diffusion current in a semiconductor?

4. Coulomb Potential

~~a)~~ What are the allowed values for each of the quantum numbers n, l, m_l, m_s?

~~b)~~ How many electrons can occupy each of following subshells: 3s, 2p, and 4d?

~~c)~~ What would happen to an atom if the Pauli Exclusion Principle did not hold?

a) $n = \{1, 2, 3, \ldots\}$ ✓

$l = \{0, 1, 2, \ldots n-1\}$ ✓

$m_l = \{0, \pm 1, \pm 2, \ldots \pm l-1\}$ $\pm l$ X

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$m_s = \pm 1/2$ ✓

b) 3s = 2

2p = 6 ✓

4d = 10

c) If the Pauli exclusion Principle didn't hold all the e^-'s would want to have the lowest Energy possible and would crowd around the nucleus. There would be no limit on how many e^-'s could have the same ψ and they would all bunch up near the nucleus. ✓

5. Lasers

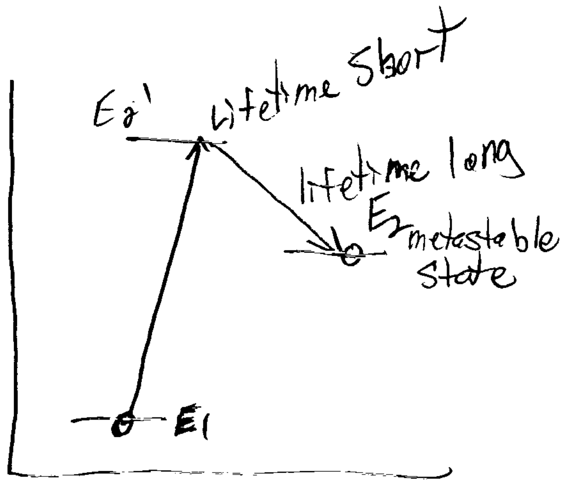
~~a)~~ Explain the difference between spontaneous and stimulated emission.

~~b)~~ What condition is necessary for optical amplification and how is it achieved? Explain using a typical energy level diagram.

~~c)~~ Why is the light from a laser nearly monochromatic? Provide one explanation for why the laser's output has a small spread in wavelength.

a) In spontaneous Emission e^-'s fall down in energy levels by themselves and emit one e^-. In stimulated emission a photon passes by the e^- and it causes it to fall down an energy level and emit a photon that is in phase with the other photon. ✓

b)



- photons are absorbed by e^-'s and they raise up to E_2' level.
- Once there they fall back down to E_2 level or to E_1. If they fall to E_2 they last at this level a long time. After a while

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☆ atoms not e^-'s

a lot of these atoms have e^-'s that are at E_2 rather than E_1. This is called a population inversion and the process to reach it is called optical pumping.

☆ A population inversion is needed for optical amplification and is when more ~~e^-'s~~ atoms are at a higher energy.

c) Light from a laser is nearly monochromatic because all the photons that are emitted carry the same energy and ~~so~~ the same λ. The reason it isn't totally monochromatic is b/c of diffraction when it passes through the end. ?x

this is what monochromatic means. why?

- The reason o/p has small spread in wavelength is the doppler effect in that when e^- is moving away from you photon emitted has a lower λ red shift. e^- moving toward you photon emitted has a higher λ blue shift. These other wavelengths create the spread in the output. ✓